HALS : OUR FUTURE LIGHT SOURCE AT NSRL *

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Abstract

Hefei Light Source (HLS) is a second generation VUV light source, whose performance is limited by large beam emittance and less insertion devices and can't meet the requirements of synchrotron radiation experiments. One year ago, the concept of Hefei Advanced Light Source (HALS) was brought forward, whose purpose is to produce VUV and soft X-ray synchrotron radiation with high brilliance and good lateral coherence. In the preliminary design study, a medium scale storage ring composed of multi bend acromat focusing structure was adopted to achieve ultra low beam emittance, less than 0.2nm·rad. In this paper, the optimization of linear and nonlinear optical parameters was introduced. The on-momentum and off-momentum dynamic aperture is large enough for bean injection. The transverse momentum aperture is larger than ±3% for acceptable beam lifetime. Finally, the expected brilliance of synchrotron radiation was calculated by SPECTRA code.

INTRODUCTION

Hefei Light Source at NSRL is a dedicated second generation VUV and soft X-ray source, designed and constructed twenty years ago. The main parameters of HLS are listed in Table 1. With the fast development of synchrotron radiation experimental techniques, the brilliance of HLS can't meet the requirements of synchrotron radiation application research. The beam emittance and number of insertion device are two limiting factors of HLS storage ring.

Table 1: Main Parameters of HLS

Parameters	Values
Energy	800 MeV
Circumference	66 m
Lattice	4×TBA
Emittance in operation	160 nm·rad
Transverse tunes	3.54 / 2.60
Natural chromaticity	-6 / -6
RF frequency	204 MHz
Straight section	4×3.36 m
Insertion devices	2 Undulators + SR Wiggler

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For enhancing the competitive capability of NSRL in VUV and soft X-ray range, the scheme of an advanced VUV and soft X-ray light source, named Hefei Advanced Light Source, was proposed by NSRL team. With the very high brilliance and better transverse coherence, the HALS will be our future advanced light source in next decades at NSRL. The design consideration of HALS and preliminary design parameters are briefly introduced in this paper.

DESIGN GOAL OF HALS

First, VUV and soft X-ray with very high brilliance were expected by SR users in China, where an advanced 3.5 GeV synchrotron radiation light source SSRF was operated in this year and is superior at X-ray region. Second, some users hope transverse coherent radiation beyond water window, corresponding photon wavelength is longer than 24Å. Third, the capacity supporting multi-users would be excellent. Except for above goals, several factors were considered also in the choice of scheme for new light source, including scale and foundation of the facility, stability and availability of the key accelerator techniques. At the present time, electron storage ring with ultra low beam emittance is preferred as the baseline configuration of HALS.

The beam energy is 1.5 GeV for production of VUV radiation by undulators and acceptable Touschek scattering effects on beam lifetime and emittance. High brilliance and transverse coherence is related to beam emittance. The design goal of beam emittance is 0.2 nm·rad. Beam emittance as well as the number and length of straight section are the measure of ring lattice design.

LATTICE DESIGN

The acceptable scale of storage ring is the main limitation in lattice design, and the maximum average radius is about 60m. The limited ring scale and emittance goal brought much difficulty in lattice design. Referred to existing light source design, emittance scaling with beam energy can reach our design goal only in very large storage ring, like ESRF, APS or SPring-8, whereas their scale and foundation are un-acceptable for us. The conceptual design of MAX IV and NSLS II give good directions for our case. Other than achievable beam emittance, the number and length of straight section are also concern.

Then, our design strategy is as following: damping wigglers is integrated with ultra low emittance storage ring to achieve design goal. The natural emittance of bare lattice should be enough low to avoid that, number of damping wiggler is more and results in less number of user insertion devices. On the other side, employment of damping wiggler should release the transverse focusing requirement of low emittance ring and enhance radiation damping, which is helpful to fight with Intra Beam Scattering effects. The natural emittance of ring is expected about 0.3 nm·rad, while the number of damping wiggler is less than 6.

Due to the limitation of ring scale, it is very difficult to obtain low beam natural emittance by using of usual DBA and TBA focusing structure. MBA is preferred because the number of dipole magnet is more and effective to reduce beam emittance, as showed in (1) [1].

$$\varepsilon[m\cdot rad] = F_1(\nu_x)F_2(lattice)\frac{E^2[GeV]}{J_x N_d^3} \qquad (1),$$

where the factor $F_1(\nu_x)$ is determined by overall transverse focusing, which would bring strong nonlinear effects if F_1 is closed to unity; the factor F_2 is determined by lattice structure and is smaller in MBA than DBA or TBA; the N_d is number of dipole and the cube dependence results in effective emittance reduction with more dipoles. At same time, we hope that, the number of straight section is more and their length is enough long for installation of user insertion devices and damping wiggler. For effectiveness of damping wiggler, the straight section would be dispersion free.

Considering achievable beam emittance and parameters of straight sections, FBA was employed firstly [2]. For saving space, combined function dipole magnet was used, which is helpful to increase horizontal damping partition number J_x. One quadrupole is located between dipoles in arcs to make acromat. To improve the adjustability of lattice, triplet was installed on the sides of straight section. It is relatively easy to adjust beta function at the middle straight section and tunes by changing the strength of triplet. Other than beam emittance, the nonlinear performance is also considered in the linear lattice design. The MAD8 [3], OPA [4] and BETA [5] code were used in lattice design study of HALS. Careful adjusting betatron phase advance per cell, the on-momentum dynamic aperture and off-momentum dynamic aperture is large enough after compensating the linear chromaticities. The Fig. 1 showed the Twiss function and dispersion function of FBA cell, and the Fig. 2 displayed the dynamic aperture. Considering transverse effects, the overall momentum aperture is larger than ±3%

As another lattice candidate, QBA was studied and optimized also. With same circumference, the number of straight section in QBA lattice is more than that in FBA by two, while the beam emittance of bare lattice is similar. The figure 3 is Twiss function and dispersion function of one cell. The on-momentum and off-momentum dynamic aperture are plotted in figure 4. The momentum aperture is larger than ±3% also.

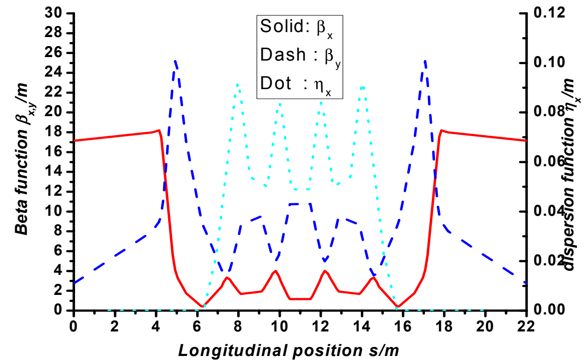

Figure 1: Twiss and dispersion function of FBA

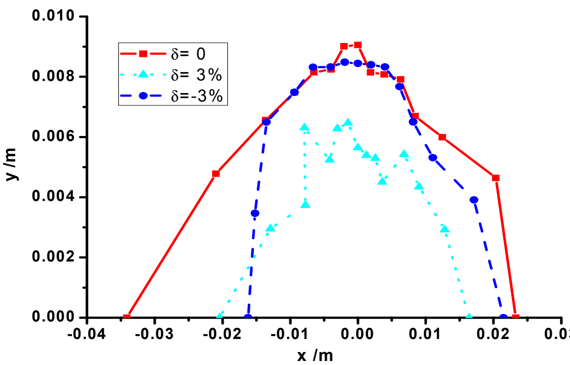

Figure 2: 1000-turn dynamic aperture of FBA

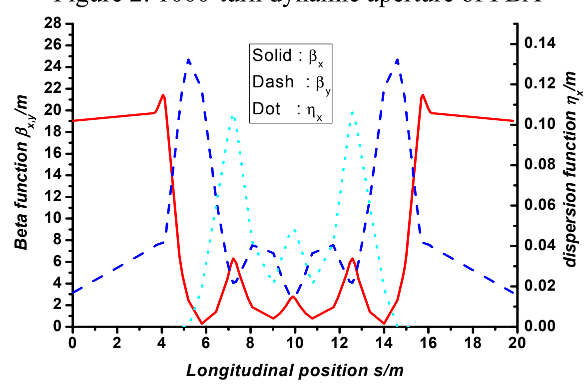

Figure 3: Twiss and dispersion function of QBA

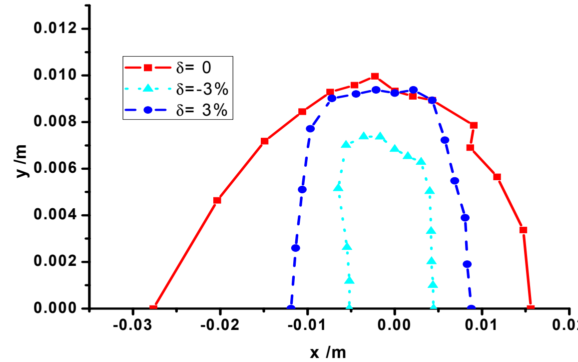

Figure 4: 1000-turn dynamic aperture of QBA

The dynamic aperture of FBA and QBA is large enough for beam injection. The transverse momentum aperture is also satisfied with the requirement of beam lifetime, which is limited by Touschek scattering effects. With help of third harmonic cavity, the beam lifetime is expected about 4 hours, than top-off injection should be used to solve lifetime problem. The minimum beam size is about ten microns when betatron coupling is 0.05, and the closed orbit shifts would less than one micron. It is possible to realize stability goal using present orbit stability techniques. The impedance budget control and powerful feedback system would be employed to overcome collective effects. High beam intensity and low beam emittance is essential for enhancing brilliance of light source. The main parameters of FBA and OBA lattice are listed in Table 2.

Table 2: Main Parameters of Designed Lattice

Parameters	FBA	QBA
Beam energy	1.5 GeV	
Circumference	396 m	
RF frequency	500 MHz	
Harmonic number	660	
Beam intensity	500 mA	
Number of dipole	90	80
Number of quadrupole	180	180
Super-period	18	20
Emittance of bare lattice	0.28nm·rad	0.31nm·rad
Transverse tunes	29.47 / 10.43	31.24 / 10.62
Natural chromaticities	- 52 / -54	-70 / -48
Momentum compaction factor	0.00047	0.00026
Damping partition number	1.77 / 1 / 1.23	1.39 / 1 / 1.61
Damping time	64 / 114 / 93 ms	63 / 88 / 55 ms
Energy loss without ID	34.8 keV/turn	45.1 keV/turn
Number of straight section	18	20
Length of straight section	7.6×18=136.8m	7.3×20=146m

UTILITY OF DAMPING WIGGLER

The natural emittance of bare lattice is larger than design goal; furthermore IBS effect would increase emittance severely due to longer radiation damping time. The utility of damping wiggler is essential to realizing design goal. The following formula was used to estimate the effects of damping wiggler on emittance [6].

$$\varepsilon_w = \frac{\varepsilon_0 + 1.21\times10^{-12}\,\dfrac{\beta_x L_w \lambda_w^2 \rho_0 B_w^5}{J_x E^3}}{1 + 7.16\times10^{-3}\,\dfrac{L_w \rho_0 B_w^2}{E^2}} \qquad (2).$$

When the period of damping wiggler is 10cm, the best and realizable wiggler field is 1.6T in FBA. When total wiggler length is about 24m, which maybe take up 4 straight section, the resulting emittance is 0.11nm·rad. On the other side, the damping time is decreased quickly and below 10ms. Considering contribution of other IDs in the ring, the emittance would be smaller. The scenario in QBA is similar. With enhanced radiation damping and harmonic cavity, the IBS effect would be relaxed. The detail study of IBS effects is undergoing.

BRILLIANCE EXPECTATION

Assuming emittance is 0.2 nm·rad, the brilliance curve in FBA storage ring was estimated by SPECTRA [7] code and showed in figure 5. The maximum brilliance is beyond 10^{21}photon/s/mm^2/mrad^2/0.1%BW. The brilliance of QBA is similar with this.

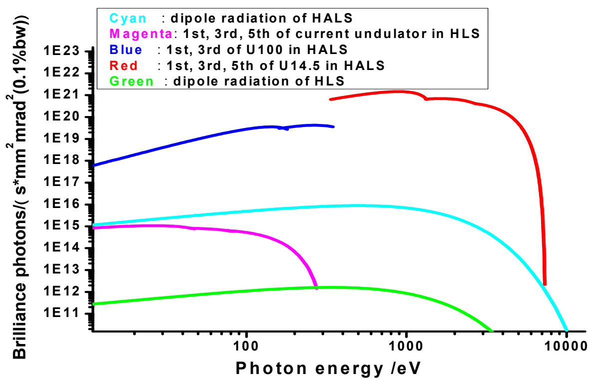

Figure 5: Expectation of brilliance of HALS and comparison with that of HLS

OUTLOOK AND ACKNOWLEDGMENT

With very high brilliance and better transverse coherence, the HALS would be one of the most advanced VUV and soft X-ray source in the world.

Under the support of CAS and USTC, the R&D of HALS is undergoing. We thank every people who is interesting in and taking care of HALS and NSRL.

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